Damage mechanisms of high energy radiation and charged dust grains in biomolecule thin films: implications for astronaut health effects. M J. Schaible[1,3], A. McKee[1], S. Kundu[1], R. Rosenberg[2], and T. M. Orlando[1,3], [1]School of Chemistry and Biochemistry, Georgia Institute of Technology, [2]Argonne National Laboratory, Advanced Photon Source, [3]REVEALS SSERVI Node (mjschaible@gatech.edu).

Introduction: The need to account for the dangers of radiation in human space exploration is well understood. Measures to provide protection from harmful ionizing radiation typically take the form of radiation shielding and dose limitation. While the physiological effects of radiation are well known (i.e. radiation sickness), less is understood about the mechanisms by which radiation creates damage, at the molecular level, to cellular constituents such as DNA, proteins, and membranes. High energy solar and cosmic rays, as well as x-ray and UV photons, produce the damage primarily through the production and interaction of low energy secondary electrons (LEE) with the organic molecules. Knowledge of the molecular level radiation damage effects caused by LEEs can help in the development of effective treatments and medical preventative methods for long-term radiation exposure.

Another well-known danger of human and robotic exploration is the electrostatic charging of regolith dust grains and their potential adhere to insulating surfaces. Ionizing radiation (IR_p, including UV photons and the ions and electrons in the solar wind and magnetospheric plamas) charges the surfaces of the grains and preferentially removes more volatile species such as oxygen. The charging and reduction of the surface can create unsatisfied chemical bonds and a potentially enhance the surface reactivity with organic molecules. Additionally, the transfer of electrons from the grain surface to biologic tissue can have potentially similar effects to those caused by high energy radiation. Therefore, it is important to have a means of discharging and passivating grain surfaces for safe exploration of airless body surfaces.

The goal of this work is to better understand the molecular level damage effects caused by ionizing radiation in space and characterize potential secondary dangers caused by highly irradiated and charged dust grains. The results obtained in this study will help determine the potentially toxic effects caused in the organic molecules of biologic tissues when they come into contact with charged dust grains.

LEE damage of nucleotides and amino acids: Several series of experiments carried out at the Advanced Photon Source have been used to determine the molecular level damage effects for LEEs on films of nucleotide and amino acid molecules (see Figure 1). These studies monitored the relative strength of oxygen, carbon and nitrogen photoelectron peaks as a function of LEE exposure using x-ray photoelectron spectroscopy (XPS). XPS is sensitive to the chemical bonding state of the elemental constituents and, when used in conjuction with high luminosity synchrotron irradiation, can be used to monitor molecular damage resulting from LEEs. The example in Figure 1 shows the O-1s photoelectron peak where O^{i} corresponds to phosphate oxygen, O^{ii} to oxygen on the sugar subunit, and O^{iii} to water co-condensed with the nucleotides. The O^{ii} component decreases with LEE exposure while the O^{i} component increases, indicating a breakage in the phosphoester bond.

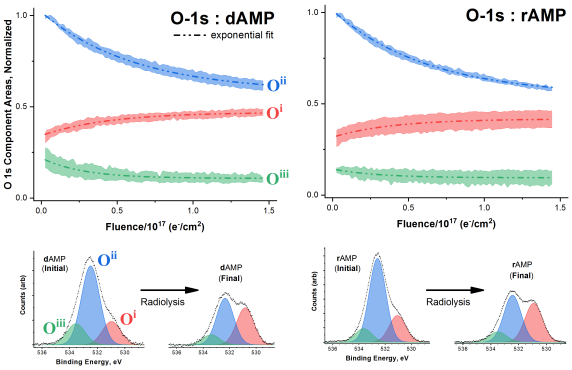

Figure 1 XPS study of LEE damage of rAMP and dAMP nucleotides. The decrease in the O^{ii} peak signifies breaking of the sugar subunit, while growth in O^{i} implies formation of phosphate oxygen.

Dust charging apparatus: Meanwhile, construction of a new apparatus capable of charging dust grains and then transporting them under high vacuum conditions to an organic substrate is under way. Changes are determined by collecting XPS and AFM measurements before and after exposure and monitoring florescence microscopy and film conductance in situ. The vacuum chamber, sample holder, Faraday tube, and landing stage designs will be presented in detail. Additionally, preliminary XPS and AFM measurements of deposited DPPC bi-layer films before and after LEE irradiation and exposure to grains will be presented.